Radioactivity - Radionuclides - Radiation
8th Multi-Media Training Course with Nuclides.net

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Radioactivity in the Environment
- Radioecology -

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Content

- Introduction to Radioecology
- Dynamics of Radionuclides in Forest Ecosystem
  - Processes of Transport and Transfer of Radiocaesium
  - View to Radiostrontium
- Summary

Radioecology

- collecting and measurement of environmental samples
- dynamics of radionuclides in ecosystems
  - identification of pathways
  - modelling of radionuclide migration
- dosimetry

Radioecology – Sampling/Measurement

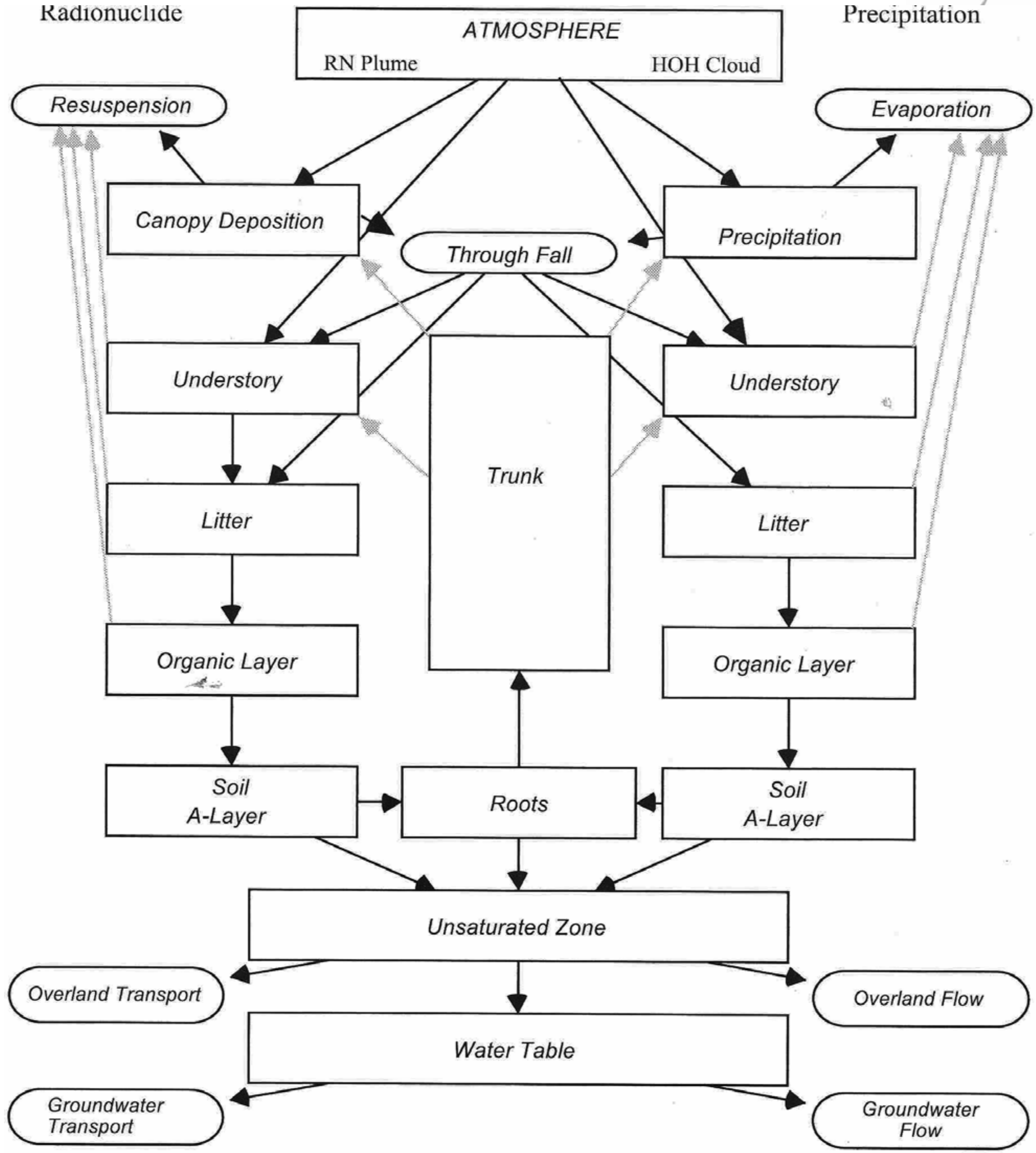
- sampling (water, aerosol particles, soils, plants)
  - selection of sampling site (incident/monitoring)
  - representative sampling (local variability)
- sample preparation (drying, concentration, ashing, milling)
  - reproducibility
  - non-changing of the measurand
- radiochemical separation
  - obligatory for determination of α and/or β-radionuclides
  - modelling of radionuclide migration
- measurement

Radioecology – Dynamics of Radionuclides

- evaluation of measurement results
- identification of pathways
- development of radionuclide migration flowchart
- simplification
- modelling / comparison with measurement results

Dynamics of Radionuclides

- example:
  forest ecosystem



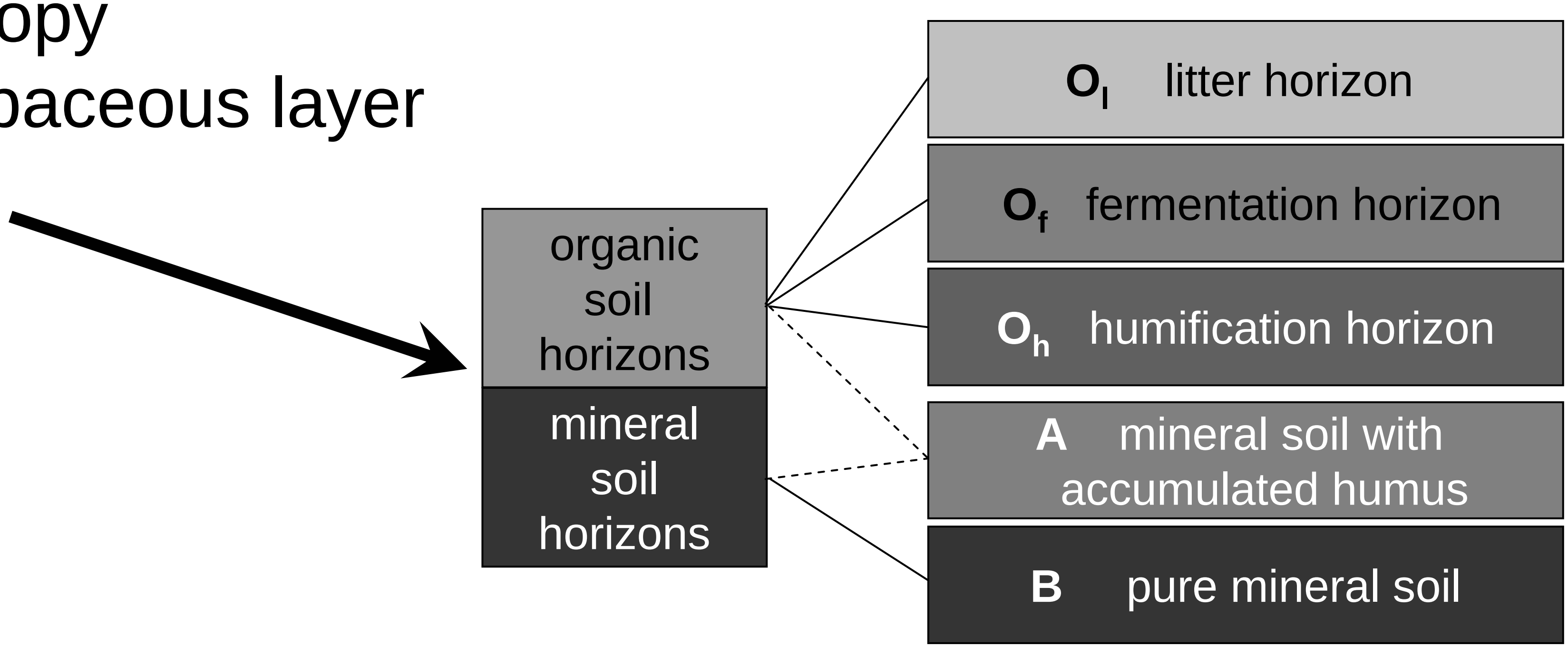
Radioecology – Dosimetry

- emergency case
  - relevant radionuclide
  - chemical/physical form
  - dose to man calculation
- monitoring
  - identification relevant radionuclide
  - identification and modelling of exposure pathways
  - dose to man calculation
  - protection of environment:
    modelling of dose to individual calculation

Introduction - Forest Ecosystem (I)

classification in environmental compartments:

1. canopy
2. herbaceous layer
3. soil



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Introduction - Forest Ecosystem (II)

characterisation of the sampling sites:

- Hochstadt: Pure Norway spruce (*Picea abies*) stand, age ~100 y, cambisol on calcareous moraine
- Siegenburg: Scots pine (*Pinus sylvestris*, ~90% of the stand) and Norway spruce (~10% of the stand), age ~120 y, podsol on nutrient - poor dune sand
- Garching/Alz: Scots pine (~30% of the stand) and Norway spruce (~70%), age ~120y, pararendsina on calcareous gravel

Actual situation: Example Germany (I)

contamination of food from forest with radiocesium is significantly higher than agricultural products:

agricultural products (**maximum** values, Bavarian RPA):

• cereal	< 0.5 Bq/kg
• beef	12 Bq/kg

Actual situation: Example Germany (II)

typical contamination in the Munich area:

- venison i.e. wild boar ~ 1 000 Bq/kg
- fungi i.e. bay boletus ~ 1 000 Bq/kg
- berry i.e.raspberry ~ 100 Bq/kg

German regulation:

prohibited to deal or bring in circulation foodstuff with a radiocesium contamination higher than 600 Bq/kg **but** self consumption is allowed

Transport and Transfer Processes (I)

1. direct deposition to the forest soil
2. weathering from the treetop

radiocesium is mobile and can be rinsed with water to the forest soil

i.e. coniferous forest at Munich area:

horizon	part of ^{134}Cs-inventory
L	24%
Of	35%
Oh	23%
Ah	4%
B	14%

Transport and Transfer Processes (II)

"Immobilisation" of Radiocesium in forest soils

1. uptake by fungal mycelia and micro-organisms
2. fixation by clay minerals

organic soil layers are the dominant pool for radiocesium longer than one decade:

- ~ 20-30% of radiocesium in fungal mycelia of the organic soil layer
- only 0.01-0.1% of radiocesium in the fungal over ground fruit bodies

part of exchangeable Cs low, but available for plants living in symbiosis with fungi

Transport and Transfer Processes (III)

vertical migration of radiocesium in forest soils

- *transport downward*:
  decomposition of litter and formation of new litter horizons by needle and leaves fall
- *transport upward:*
  transport of radiocesium in fungal mycelia by colonisation of fresh litter

nearly compensation of down- and upward transport

→ slow going marcoskopic shifting to deeper forest soil layer

Modelling of the Migration (I)

- insufficient knowledge about the relevant dynamic processes in forests

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a detailed modelling is impossible

- “black-box” description of the migration processes of radiocesium in forest soils by using the compartment model

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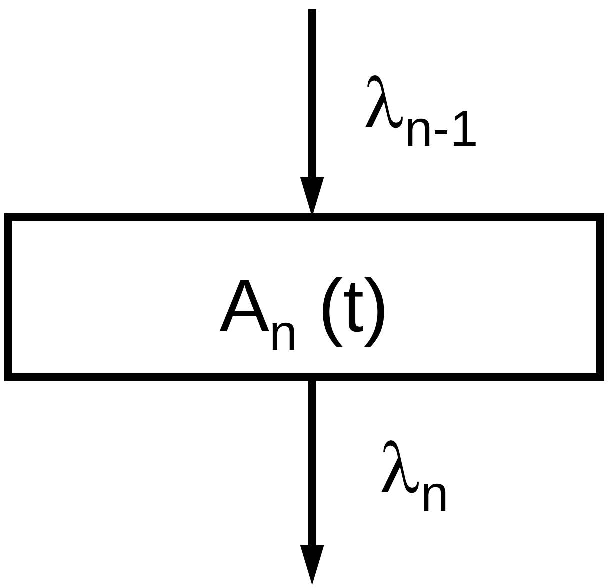
Modelling of the Migration (II)



$$\frac{d}{dt}A_n(t) = \lambda_{n-1}A_{n-1}(t) - \lambda_n A_n(t)$$

with:

A_n (t) time dependent compartment activity (decay corrected) in Bq/m²

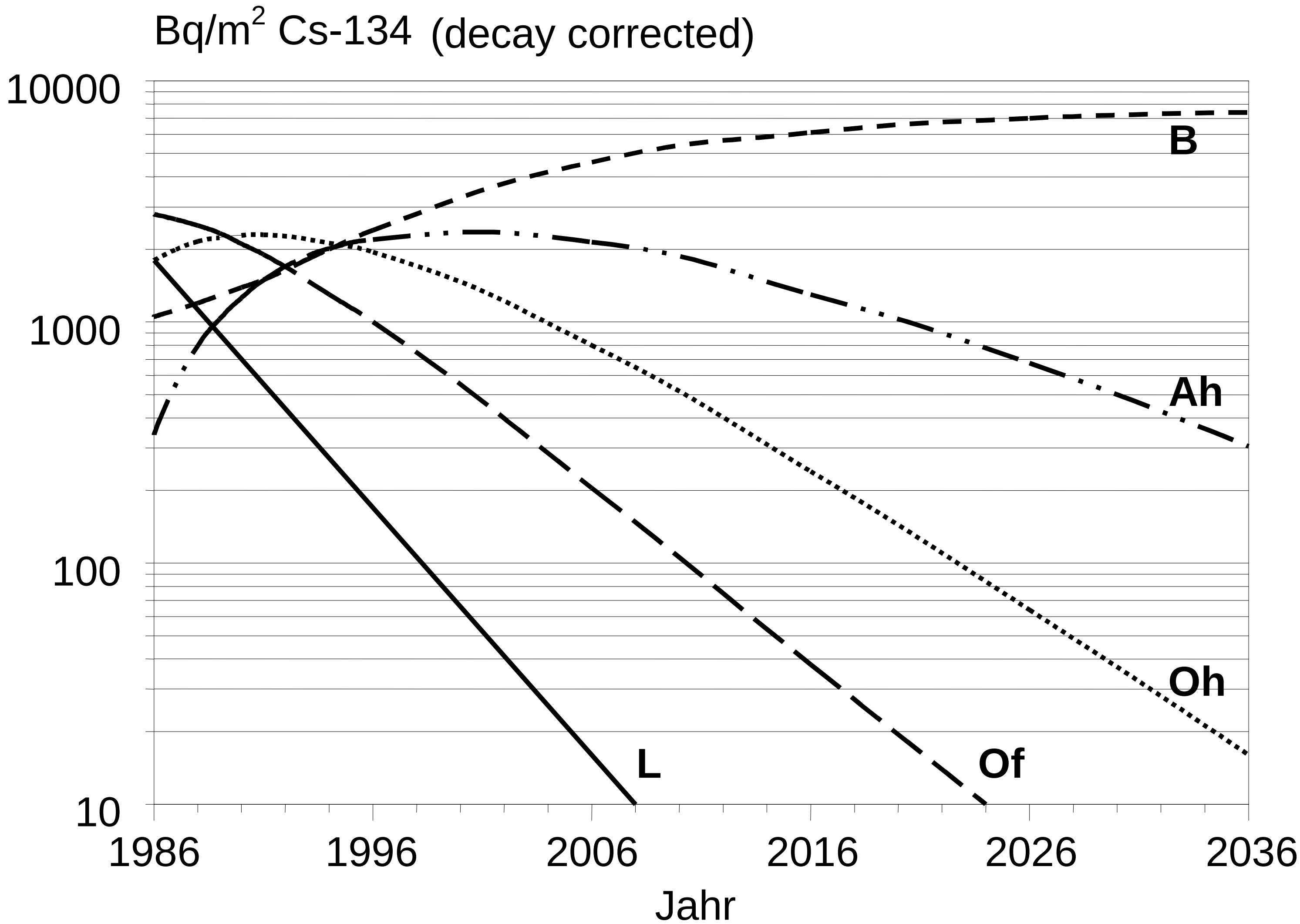
λ_n rate coefficient in 1/a

(in correlation with ecological half-life $T_{1/2,n}^{eco}$ via $T_{1/2,n}^{eco} = \ln 2 / \lambda_n$)

Modelling of the Migration (III)

results: ecological half-life

horizon	O_l	O_f	O_h	A_h
$T_{1/2}^{eco}$ (a)	2.8±0.5	3.8±0.8	4.4±1.2	7.7±4.9
$T_{1/2}^{eco}$ (a/cm)	4.0±0.7	2.5±0.5	2.4±0.7	7.0±4.5


Bq/m2 Cs-134 (decay corrected)
10000
1000
100
10
1986
1996
2006
2016
2026
2036
Jahr
B
Ah
Oh
L
Of

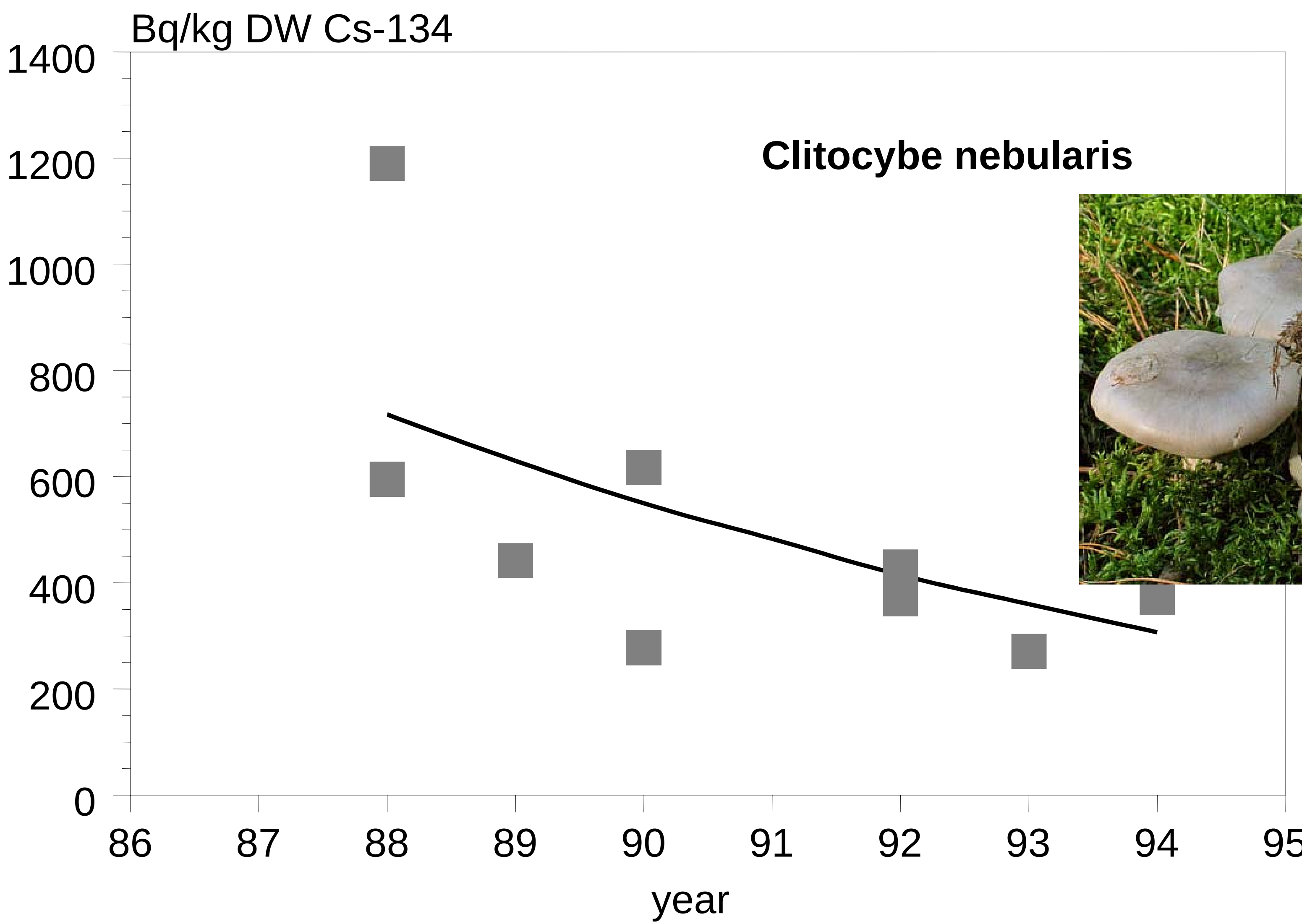
Consequences of Cs-migration in soil

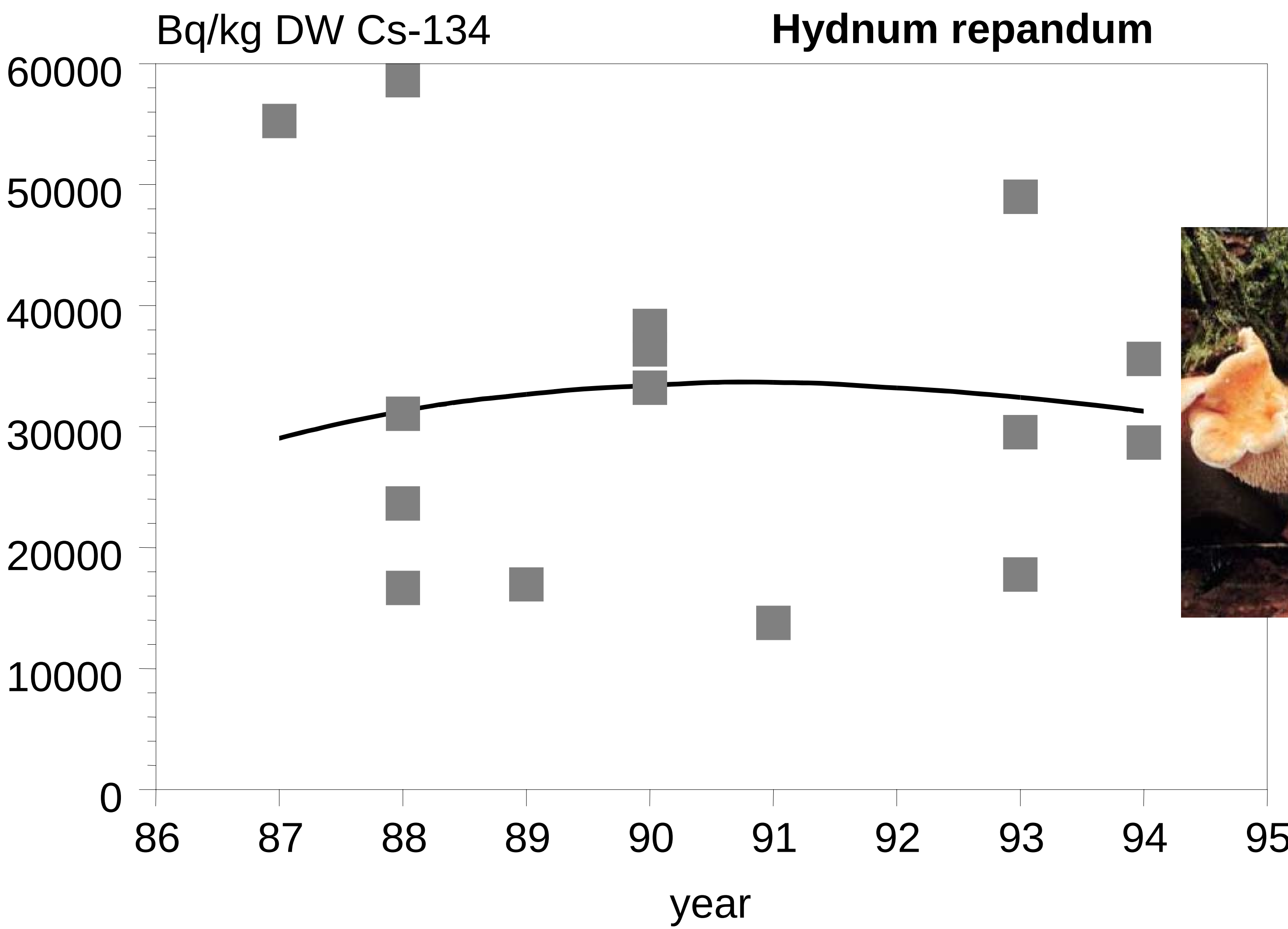
example: **Fungi**

- location of mycelia in forest soil influence the contamination of the fruit body:

  the time dependent contamination of the fruit body reflect the time dependent contamination of soil layer populating the mycelia

- the absolute value of contamination is species- and sitespecific


Bq/kg DW Cs-134
Clitocybe nebularis
1400
1200
1000
800
600
400
200
0
86
87
88
89
90
91
92
93
94
95
year


Bq/kg DW Cs-134
Hydnum repandum
60000
50000
40000
30000
20000
10000
0
86
87
88
89
90
91
92
93
94
95
year

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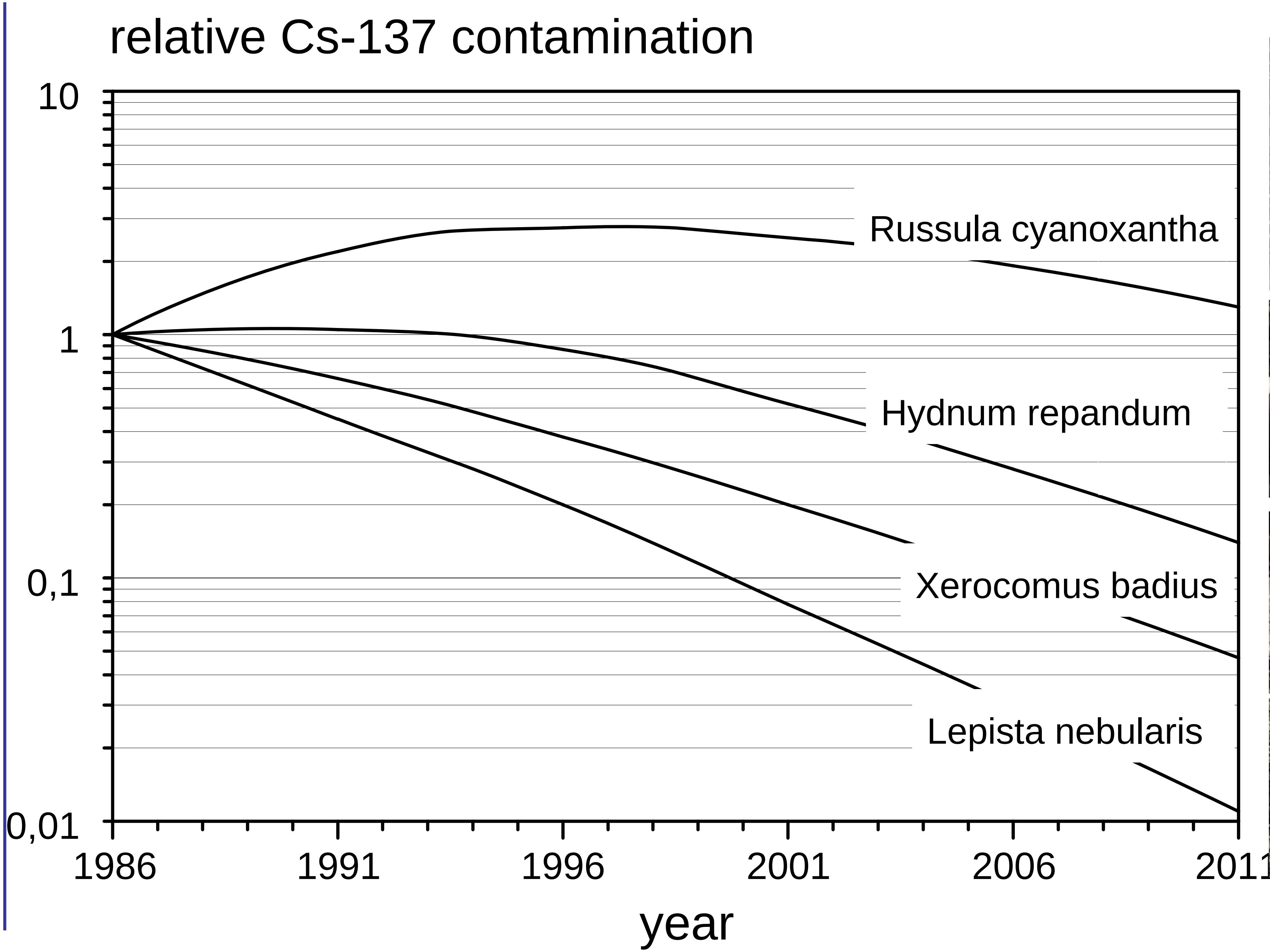

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Consequences of Cs-migration in soil

example: **wild boars**

- unchanged high contamination of flesh, light increasing tendency
- not a local phenomenon: Bavarian Forest, Palatinate Forest
- radiocesium contamination of flesh in Bavarian Forest in 2002:
  - 57 samples were investigated
  - only 1 sample lower than 600 Bq/kg
  - average value 6 400 Bq/kg
  - range of values: 430 - 20 000 Bg/kg

Consequences of Cs-migration in soil

wild boars take radiocesium via fodder:

- “tree-mast” (i.e. acorn, beech-nut, chest-nut)
- fodder from agricultural production

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low contamination

Consequences of Cs-migration in soil

wild boars take radiocesium via fodder:

- closed and large area forest
- vegetable and animal nutrition from the forest soils

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high contamination

deer truffle:

- grow below ground, eaten by wild boar as a delicacy
- maximum value 122 000 Bq/kg of radiocesium in Bavarian Forest in 2002

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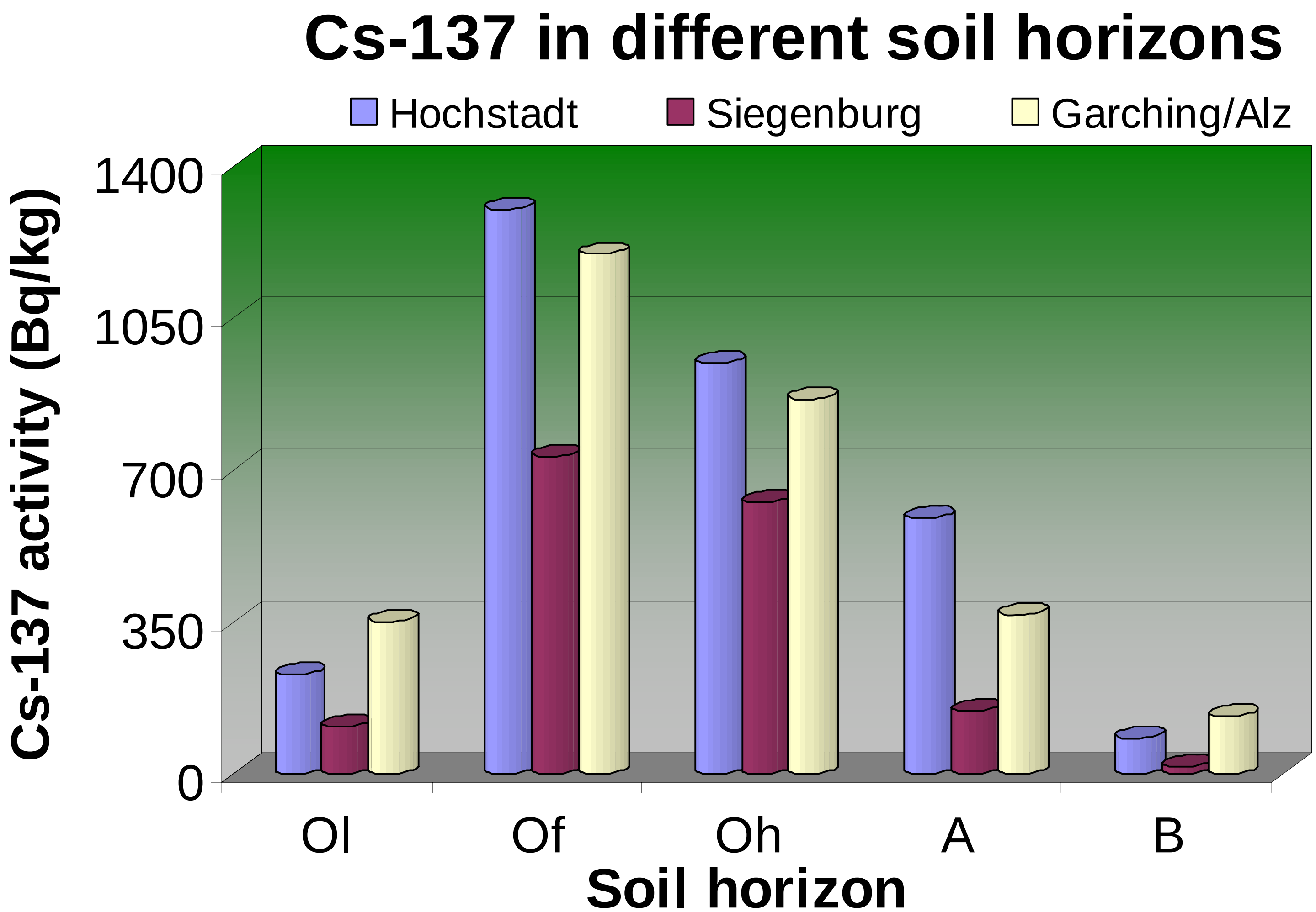
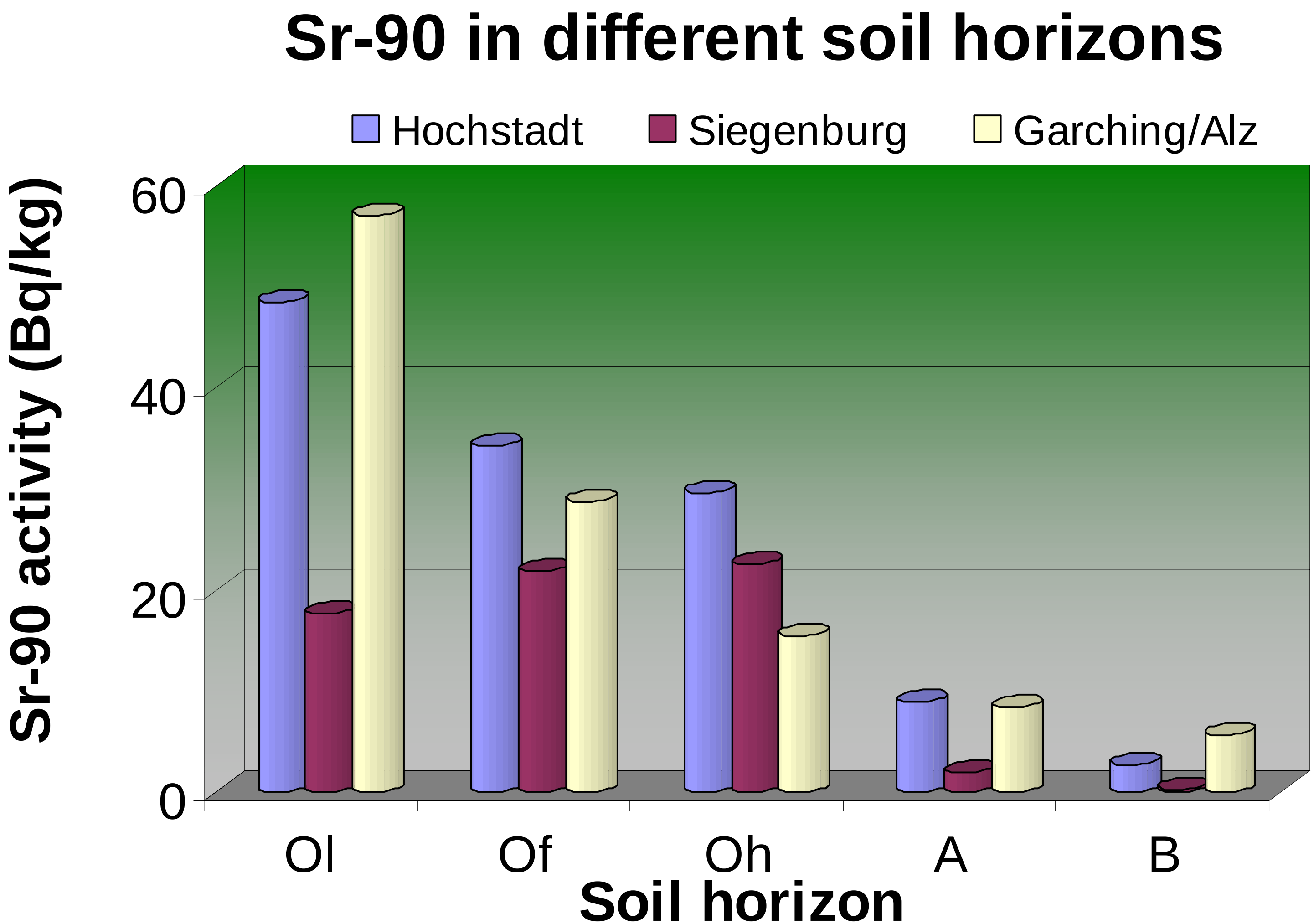
Summary: Radiocesium



View to Radiostrontium



Radiostrontium in Fungi

Fungal species	Sampling site	Sr-90 activity (Bq/kg(dw))
Armillaria mellea	Hochstadt	6.2
Collybia butyracea	Hochstadt	2.7
Russula nigricans	Hochstadt	4.8
Sarcodon imbricatus	Hochstadt	< 0.4
Boletus felleus	Siegenburg	< 0.5
Xerocomus badius	Siegenburg	< 0.3
Russula sardonia	Siegenburg	< 0.4
Agaricus silvaticus	Garching/Alz	2.2
Lactarius deterrimus	Garching/Alz	1.0

Radiostrontium in understory vegetation

		Sr-90 activity (Bq/kg (dw))		
		Hochstadt	**Siegenburg**	**Garching/Alz**
blackberry	fruit	10.3	10.6	4.0
	leaf	32.8	37.1	8.4
	stalk	27.2	41.2	6.4
raspberry	fruit	6.4	5.4	6.5
	leaf	20.4	26.3	7.8
	stalk	27.7	35.3	n.d.
bilberry	fruit	2.7	6.5	2.8
	leaf	9.1	37.3	11.9
	stalk	10.8	49.6	20.2

Transfer Factors

$$TF = \frac{^{90}Sr_{plant}}{^{90}Sr_{organic\ soil\ horizon}}$$

Fungal species	Sampling site	Transfer factor for Sr-90
Armillaria mellea	Hochstadt	0.18
Collybia butyracea	Hochstadt	0.08
Russula nigricans	Hochstadt	0.14
Agaricus silvaticus	Garching/Alz	0.08
Lactarius deterrimus	Garching/Alz	0.04

Transfer Factors

		Transfer factor for Sr-90		
		Hochstadt	Siegenburg	Garching/Alz
blackberry	fruit	0.30	0.49	0.15
	leaf	0.96	1.73	0.30
	stalk	0.80	1.93	0.23
raspberry	fruit	0.19	0.25	0.24
	leaf	0.60	1.23	0.29
	stalk	0.81	1.65	n.d.
bilberry	fruit	0.08	0.30	0.10
	leaf	0.27	1.74	0.44
	stalk	0.32	2.32	0.74

Conclusion

- activity level of radiostrontium in fungal mycelia is lower than that of radiocesium
- upward transport mediated by fungal mycelia is expected to be less important for radiostrontium
- surprisingly high specific activity of radiostrontium in the litter horizon

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efficient transfer from soil to plants and a continuos supply to the litter horizon via leaf-turnover

Summary

- dynamic behaviour of Cs-137 and Sr-90 is governed by different mechanisms

radiocesium:

fungal mycelia are important for mobilisation, translocation and uptake by plants → long retention period in organic soil horizons

radiostrontium:

different vertical profiles suggest en effective transfer from soil to plants and a continuos supply to the litter horizon via leaf-turnover

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Thank you for your attention!